THE MECHANISMS CONTROLLING HEAT AND MASS TRANSFER ON FRYING OF BEEF BURGERS

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Introduction

During thermal processing, such as frying, minced meat products lose weight as a result of heat denaturation and contraction of the meat proteins. There is a need to understand the mechanisms controlling heat and mass transfer during frying in order to minimise frying losses and frying time, while at the same time achieving a tender and juicy product and ensuring a safe product, having a core temperature of 72°C.

Cooking loss can be divided into two main components, namely, moisture and fat loss. Moisture can be lost either as vapour through the crust-core interface or as drip, while fat leaves the patty only in the form of drip, since at normal frying temperatures fat does not vaporise. In this study an overall approach has been taken, considering both water and fat transport, heat transfer, shrinkage and porosity development during double-sided pan frying of beef burgers to gain better understanding of the main mechanisms governing these phenomena.

Special emphasis has been put on investigating the fraction of water loss achieved by drip and vaporisation, respectively. The effects of different factors such as the chemical composition of the meat raw material, the pan temperature and the meat patty diameter on the characteristics of heat and mass transfer were studied. The evolution of the characteristics of heat and mass transfer was investigated as a function of frying time. Ultimately, a technique was developed to measure the permeability of the porous meat patty. This property and the related mass transfer were observed at different cooking temperatures up to 80°C.

Materials and Methods

Material: Different beef meat material (Shank, Lean Brisket, Rib and Fat Brisket) have been used to obtain beef burgers of low, medium and high fat content.

Frying procedure: A double-sided pan fryer with heating surfaces of 100, 150 and 175°C was used. In all the frying experiments the beef burgers were fried from -20°C until a temperature of 72°C at the centre of the beef burger was reached.

Heat transfer: For the temperature measurements two K-type thermocouples (T/T-40-K) were used, one at the centre and one 2mm below the surface.

Mass transfer: Water and fat loss were calculated as a percentage related to the weight of the raw beefburger. The flux of water and fat was calculated, by dividing the water and fat loss by the original total and lateral area of the beefburger and by the total frying time

Porosity and permeability: The air-filled porosity [%] was calculated from the volume derived from the difference between the calculated meat patty volume related to fat and water losses, and the volume calculated from the diameter shrinkage. The intrinsic permeability of the heat-treated beefburgers (K) was calculated by Darcy´s law : $K = \frac{\bar{u} \cdot \mu \cdot \Delta x}{\Delta P}$ where u is the flux of water and fat [m·s^{-1}], μ is the viscosity of water or fat [kg·m^{-1}·s^{-1}], Δx is the height of the beefburger [m], ΔP is the pressure gradient [Pa].

Results and Discussion

The most determinant factor for the water flux is the temperature gradient, and for the fat flux, the fat content.

The water flux during the first 90 seconds of frying (thawing period) decreases. However, most of the water is lost during that period. After 90 seconds crust formation starts and the water flux increases, probably due to the enhancement of water loss by evaporation through the crust-core interface. The fat content governs both the amount and the initial time of the fat release during frying. The higher the rate of heat penetration, by using beef burgers of smaller diameters and higher cooking temperature, the higher the rate of water losses induced and the faster the crust is formed, which in turn results in less shrinkage and higher porosity of the heat processed meat. The highest permeability value was found in beef burgers prepared from the meat cooked at 60°C, where after the highest contraction between 60 and 70°C caused a much denser beef burger. The main mechanism for mass transfer during frying was suggested to be a flow of fat and water, created due to the denaturation and contraction of the meat proteins, and moving firstly inwards and there after in the radial direction and ultimately migrating out through the circumference of the burger. Therefore the pressure-driven water loss, i.e. drip, is the main mechanism governing the water loss in the frying of beefburgers and not the evaporation of water.

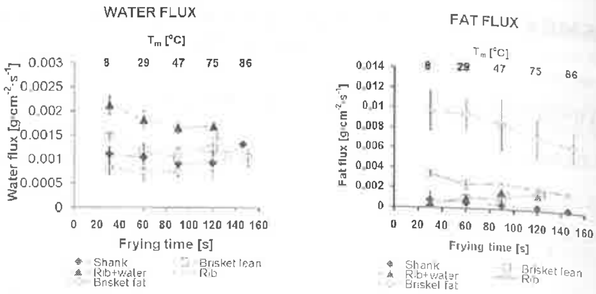

Figure 1: Water and fat flux as a function of the frying time and the average temperature for beefburgers made of five different meat raw materials.

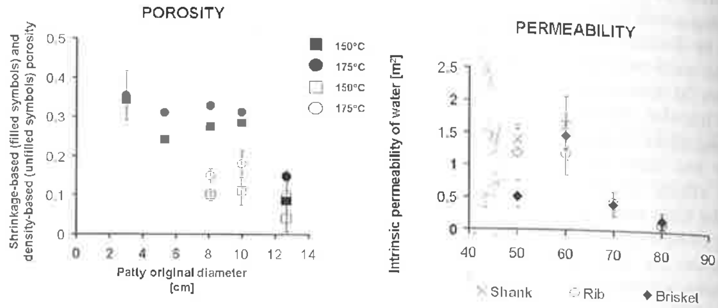

Figure 2: Porosity as a function of original patty diameter at 150°C and 175°C pan temperature and permeability of beefburgers, using different meat raw materials, as a function of endpoint-temperature.

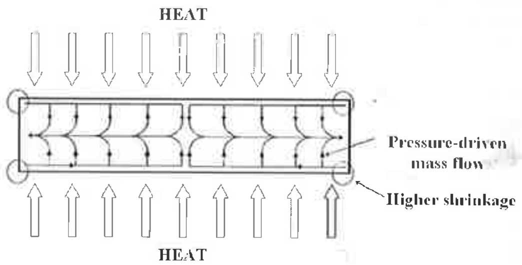

Figure 3: Schematic drawing of heat and mass transfer in the beefburger during double-sided pan frying.

Conclusions

As a result of the thermal denaturation and contraction of the meat proteins during pan-frying of beefburgers, a flow of water and fat is created moving towards the centre of the patty, which in turn speeds up the heat transfer. The water and fat drip leaves the patty through the circumference of the burger.

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